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"Studies of a Free-Flying Astromag Mission"

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Final Report
on
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Studies of a Free-Flying Astromag Mission

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April 7, 1995

Abstract: This is the final report on work funded by NASA grant NAGW5-2168 entitled "Studies of a Free-Flying Astromag Mission". This grant was originally funded to cover the period from 1 November 1992 to 30 April 1993. Following this a no-cost extension was granted that extended to 12/31/93.

Introduction: In 1989, after extensive study (Ormes et al. 1986), the Astromag Superconducting Magnet Facility was selected for flight on the Space Station, including three experiments, Wizard, LISA, and SCIN-MAGIC. Two years later, Astromag and a number of other payloads were indefinitely suspended from consideration from flight on Freedom when the Space Station was descoped. Subsequent to this, a new study carried out by Goddard Space Flight Center (Ormes et al. 1990) determined that the vast majority of the objectives of Astromag could also be carried out by a free-flying mission launched by an Atlas-IIAS rocket. Following the NASA Woods Hole planning meeting in 1991, it was clear that overall mission costs would be a primary consideration for determining the experiments that NASA ultimately selected for spaceflight.

It was within this climate that a small amount of money was made available to determine whether the costs of Astromag could be further reduced, without sacrificing its primary science objectives, by accomodating it on a Delta launch vehicle. The study summarized in this final report is part of that effort. The objective of this study was to determine to what extent the objectives of the LISA Experiment could be accomplished by a scaled-down instrumentation and a smaller magnet compatible with the resources available on a Delta-class mission.

The scientific objectives of the LISA experiment (see Binns et al. 1989) are to 1) extend measurements of the isotopic composition of cosmic ray elements from Be to Ni (Z = 4 to 28) into the energy range beyond 1 GeV per nucleon; 2) to measure the energy spectra of heavy elements up to energies >100 GeV/nucleon with good statistical accuracy, and 3) to search for heavy anti-matter with Z>2 in cosmic rays. In the present study the SRL group proposed to study three topics. The results obtained in each of these areas are summarized below.

1) Adaption of the LISA Cherenkov Counters to a Smaller Size Astromag: For orientation, Figure 1 shows a cross section of the LISA experiment for the Space Station and Atlas versions of Astromag. The key subsystems are the magnet, the tracking system, the Cherenkov system, consisting of a number of modules, and the TOF system. During the course of this study GSFC considered various possible accomodations of Astromag within a Delta Launch vehicle, along with a number of possible orbits and design lifetimes. As a result, the mass and power allocated to the instruments was constantly changing, and several different versions of smaller size experiments were considered. Figures 2, 3, 4, and 5 show rough sketches of seven possible versions, all of which fit within the 2.5 m radius of a Delta shroud.

In order to provide quick feedback on the required resources for these various versions a spreadsheet was developed that included scaling laws to estimate the mass and power of not only the Cherenkov system, but also the LISA experiment as a whole, since the overall design of LISA was driven by the number of Cherenkov modules. Table 1 shows a detailed breakdown for the Cherenkov subsystem for nine possible versions. Among the weight-saving modifications that were introduced were VLSI electronic circuitry (see below), and carbon fiber structural support.

A summary of these mass and power estimates for the first seven options is included in the attached report dated 10/26/92. On the basis of estimates such as these it was decided that a LISA experiment could indeed be built for ~350 to 400 kg. Table 2 includes a total of ten options that were considered, along with the Atlas version.

2) Application of new VLSI Circuitry to Astromag: One development that can facilitate a smaller version of Astromag is the use of new, low-power electronics. One objective of this study was to determine whether the custom VLSI circuitry developed by the SRL group for use on the Advanced Composition Explorer (ACE) Mission could be used in the Astromag Cherenkov counter. In particular ACE is developing a single CMOS VLSI circuit that contains 16 complete pulse-height nalysis chains, each including a preamp, dual level discriminator, sample and hold, 12-bit Wilkinson ADC and test pulser (see Cook et al. 1993). It operates on only 15 mW per chain for a total of 240 mW of regulated power.

Although the ACE circuitry was not available in time to test it directly with the Hamamatsu phototubes (PMTs) base-lined for LISA, the design characteristics of this circuit are compatible with the application in LISA. Assuming that a given PMT would typically see ~3 photoelectrons per relativistic particle with $Z=1$ and $\beta=1$, the 30 pC full scale and dynamic range of >1000 could accomodate relativistic Ni nuclei with $Z=28$, at the same time as slow Be nuclei ($Z=4$). The required PMT gain is $<10^5$. The maximum conversion time of 256 microseconds is also compatible with the expected event rate. Thus it does appear that these circuits would be very useful in the Cherenkov system at least. The estimated savings would be ~85 mW per ADC.

3) Studies of the Mass Resolution and Yield of a Scaled-down LISA Instrument: Figure 6 shows the orbit-averaged energy spectra for several possible orbits. In its original configuration, LISA was limited to particles greater than ~2 GeV/nucleon by the 28.5 deg orbit of Freedom. As a free flyer, Astromag would no longer be restricted to low latitudes. As a result, the reduced yield implied by a smaller experiment could, to a large extent, be compensated for by the more favorable orbit. Table 3 compares the relative yield of isotopes for the Space Station, Atlas, and Delta versions. Note that with a higher inclination orbit, a smaller Astromag can still obtain sufficient satistical accuracy for high energy isotope studies.

A second advantage of a high-latitude orbit is that allows isotopic studies over a much wider range of energies than did the original Astromag orbit. By choosing aerogel radiators with several indices of refraction from ~1.1 down to ~1.025, the range from ~1 to ~4 GeV/nuc can be covered. Aerogel Cherenkov counters with n=1.043 were sucessfully tested in a recent balloon experiment (Laborador et al. 1993)

The smaller magnet in the Delta-class version of Astromag will have a somewhat reduced bending power, often characterized as the maximum detectable rigidity (MDR). The Delta version could have an MDR of 1.3 TV, compared to 2.4 TV for the Atlas Version, and 3.2 TV for the Space Station magnet. This will limit somewhat the mass resolution of heavier isotopes at high energy. Figure 7 shows the maximum energy to which isotopes can be resolved if the mass resolution contribution of the magbetic spectrometer is limited to 0.2 amu. Figures 8 and 9 calculated by Bob Streitmatter, show the expected mass resolution as a function of energy for Si and Fe isotopes. While it will be difficult to resolve adjacent isotopes with Z>20 at energies > 2 GeV/nuc, there are a number of important isotope ratios that are separated by 2 amu, including $^{54}Fe/^{56}Fe$, $^{57}Co/^{59}Co$, and $^{60}Ni/^{58}Ni$, where the required mass resolution is less.

Summary: The results of this study were that the scientific objectives of LISA could indeed be accomplished by a Delta-class version of Astromag.

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Table 1 (9 pages)

LISA Cerenkov for Possible Delta Versions

Delta Version#1

Version 1 simply shows the effect of the changes from the memo of 2/12/91
(e.g., use of VLSI and composities, inclusion of Silgard potting)

Index Ref	Tmin GeV/n	x cm	y cm	z cm	density g/cm3	Rad Wt kg	Rad Frame kg	Box Wt kg	# tbs	Tube Wt	Lin. Elec. Wt	Tot. Cntr Wt	Tot. Cntr Pow	A	B	T/B
1.025	3.35	63	52	3	0.12	1.17	2.00	6.6	6	7.4	1.2	18.4	0.9	1	1	.062
1.025	3.35	50	50	3	0.12	0.89	1.74	5.3	6	7.4	1.2	16.6	0.9	1	1	.077
1.040		63	52	3	0.19	1.87	2.00	6.6	6	7.4	1.2	19.1	0.9	1	1	.062
1.040		50	52	3	0.19	1.49	1.78	5.5	6	7.4	1.2	17.4	0.9	1	1	.075
1.060		63	52	3	0.29	2.81	2.00	6.6	6	7.4	1.2	20.1	0.9	1	1	.062
1.060		56	52	3	0.29	2.50	1.88	6	6	7.4	1.2	19.0	0.9	1	1	.069
1.100	1.3	48	48	2.5	0.48	2.74	1.67	5	6	7.4	1.2	18.1	0.9	1	1	.083
1.100	1.3	63	48	2.5	0.48	3.60	1.93	6.2	6	7.4	1.2	20.4	0.9	1	1	.066
1.150	0.96	56	42	2.2	0.71	3.70	1.71	5.1	6	7.4	1.2	19.1	0.9	1	1	.081
1.150	0.96	42	42	2.2	0.71	2.77	1.46	4.1	6	7.4	1.2	16.9	0.9	1	1	.101
1.340	0.48	56	52	1.25	2.20	8.01	0.94	6	6	7.4	1.2	23.6	0.9	0	1	.069
1.340	0.48	50	52	1.25	2.20	7.15	0.89	5.5	6	7.4	1.2	22.2	0.9	0	1	.075
1.500	0.32	72	58	1.25	1.20	6.26	1.13	8.1	6	7.4	1.2	24.1	0.9	3	3	.051
1.500	0.32	65	58	1.25	1.20	5.66	1.07	7.4	6	7.4	1.2	22.8	0.9	2	3	.056
																.071

Pow. of Counter A (W)	20		W	Had been 50 W. for 3x2 module Atlas version
Wt. of Config. A (kg)	308	678	lbs	Had been 326 kg
Number of PMTs =	90			Had been 90
Pow. of Counter A (W)	24		W	Had been 60 W for 3x3 module Atlas version
Wt. of Config. B (kg)	378	831	lbs	Had been 400 kg
Number of PMTs =	108			Had been 108

Modifications from Atlas memo of 2/12/91

1) Frame wt is now measured to be 2.02 kg for 50x50 Al frame (SMS memo of 10/9/92)
2) Assume that Composite frames can be done for 60% of Al
3) Silgard potting measured to be 0.53 kg for 50x50 radiator
4) Assume wt of electronics/tube => 0.2 kg from 0.4 kg due to use of VLSI
5) Power per ADC chain goes to 0.02 W from 0.35 W (VLSI)
6) Scale filtering and converting wt/power as number of PMTs

Version #2

Version 2 goes to 2 top and 2 bottom modules, each with 3 counters of 4 tubes each

Top radiators are 60x42 (outer), 55x42 (mid), and 50x42 (inner).

Bottom radiators are 55x42 (outer), 50x42 (mid), and 45x42 (inner).

Two radiator selections are indicated (A and B)

This is the ligghtest possible version with 3 C-counters/module

Index Ref	Tmin GeV/n	x cm	y cm	z cm	density g/cm3	Rad Wt kg	Rad Frame kg	Box Wt kg	# tbs	Tube Wt	Lin. Elec. Wt	Tot. Cntr Wt	Tot. Cntr Pow	A	B	T/B
1.025	3.35	55	50	3	0.12	0.98	1.83	5.7	6	7.4	1.2	17.2	0.9	1	1	.072
1.025	3.35	50	50	3	0.12	0.89	1.74	5.3	6	7.4	1.2	16.6	0.9	1	1	.077
1.040		55	50	3	0.19	1.57	1.83	5.7	6	7.4	1.2	17.8	0.9	1	1	.072
1.040		50	50	3	0.19	1.43	1.74	5.3	6	7.4	1.2	17.1	0.9	1	1	.077
1.080		50	50	2.7	0.38	2.57	1.74	5.3	6	7.4	1.2	18.3	0.9	1	0	.077
1.080		45	50	2.7	0.38	2.31	1.65	4.9	6	7.4	1.2	17.5	0.9	1	0	.084
1.100	1.3	55	50	2.5	0.48	3.27	1.83	5.7	6	7.4	1.2	19.5	0.9	0	1	.072
1.100	1.3	50	50	2.5	0.48	2.98	1.74	5.3	6	7.4	1.2	18.7	0.9	0	1	.077
1.150	0.96	50	50	2.2	0.71	3.93	1.74	5.3	6	7.4	1.2	19.6	0.9	1	0	.077
1.150	0.96	45	50	2.2	0.71	3.54	1.65	4.9	6	7.4	1.2	18.7	0.9	1	0	.084
1.340	0.48	50	50	1.25	2.20	6.88	0.87	5.3	6	7.4	1.2	21.7	0.9	0	1	.077
1.340	0.48	45	50	1.25	2.20	6.19	0.83	4.9	6	7.4	1.2	20.6	0.9	0	1	.084
1.500	0.32	60	50	1.25	1.20	4.50	0.96	6.2	6	7.4	1.2	20.3	0.9	2	2	.067
1.500	0.32	55	50	1.25	1.20	4.13	0.91	5.7	6	7.4	1.2	19.4	0.9	2	2	.072
														12	12	.076

Pow. of Counter A (W)	17			Had been 50 W. for 3x2 Atlas version
Wt. of Config. A (kg)	226	498	lbs	Had been 326 kg
Number of PMTs =	72			Had been 90
Pow. of Counter A (W)	17			Had been 60 W for 3x3 module version
Wt. of Config. B (kg)	233	512	lbs	Had been 400 kg
Number of PMTs =	72			Had been 108

Delta Version #3

Version 3 reduces the # counters per module to 2 from 3. No more Pilot just for Z id.

Top radiators are 65x45 (outer), 60x45 (inner); Still 6 tubes/counter

Bottom radiators are 60x45 (outer), 55x45 (inner); Still 6 tubes/counter

Two radiator selections are indicated (A and B)

Index Ref	Tmin GeV/n	x cm	y cm	z cm	density g/cm3	Rad Wt kg	Rad Frame kg	Box Wt kg	# tbs	Tube Wt	Lin. Elec. Wt	Tot. Cntr Wt	Tot. Cntr Pow	A	B	T/B
1.025	3.35	65	50	3	0.12	1.16	2.00	6.6	6	7.4	1.2	18.4	0.9	1	1	.063
1.025	3.35	60	50	3	0.12	1.07	1.92	6.2	6	7.4	1.2	17.8	0.9	1	1	.067
1.040		65	50	3	0.19	1.86	2.00	6.6	6	7.4	1.2	19.1	0.9	1	1	.063
1.040		60	50	3	0.19	1.71	1.92	6.2	6	7.4	1.2	18.4	0.9	1	1	.067
1.080		60	50	2.7	0.38	3.09	1.92	6.2	6	7.4	1.2	19.8	0.9	1	0	.067
1.080		55	50	2.7	0.38	2.83	1.83	5.7	6	7.4	1.2	19.0	0.9	1	0	.072
1.100	1.3	60	50	2.5	0.48	3.57	1.92	6.2	6	7.4	1.2	20.3	0.9	0	1	.067
1.100	1.3	55	50	2.5	0.48	3.27	1.83	5.7	6	7.4	1.2	19.5	0.9	0	1	.072
1.150	0.96	60	50	2.2	0.71	4.71	1.92	6.2	6	7.4	1.2	21.4	0.9	1	0	.067
1.150	0.96	55	50	2.2	0.71	4.32	1.83	5.7	6	7.4	1.2	20.5	0.9	1	0	.072
1.340	0.48	55	50	1.25	2.20	7.56	0.91	5.7	6	7.4	1.2	22.9	0.9	0	1	.072
1.340	0.48	50	50	1.25	2.20	6.88	0.87	5.3	6	7.4	1.2	21.7	0.9	0	0	.077
1.500	0.32	60	50	1.25	1.20	4.50	0.96	6.2	6	7.4	1.2	20.3	0.9	0	1	.067
1.500	0.32	60	50	1.25	1.20	4.50	0.96	6.2	6	7.4	1.2	20.3	0.9	0	0	.067
														8	8	.068

Pow. of Counter A (W)	11.7			Had been 50 W. for 3x2 Atlas version
Wt. of Config. A (kg)	157	346	lbs	Had been 326 kg
Number of PMTs =	48			Had been 90
Pow. of Counter A (W)	11.7			Had been 60 W for 3x3 module version
Wt. of Config. B (kg)	159	350	lbs	Had been 400 kg
Number of PMTs =	48			Had been 108

Delta Version #4

Version 4 has 2 counters per module as does #3.

Top radiators are 60x45 (outer), 55x45 (inner);

Bottom radiators are 55x45 (outer), 50x45 (inner);

Now have 6 PMTs on outer counter, only 4 on inner

Two radiator selections are indicated (A and B)

Index Ref	Tmin GeV/n	x cm	y cm	z cm	density g/cm3	Rad Wt kg	Rad Frame kg	Box Wt kg	# tbs	Tube Wt	Lin. Elec. Wt	Tot. Cntr Wt	Tot. Cntr Pow	A	B	T/B
1.025	3.35	60	45	3	0.12	0.96	1.83	5.7	6	7.4	1.2	17.1	0.9	1	1	.073
1.025	3.35	55	45	3	0.12	0.88	1.74	5.3	4	5	0.8	13.7	0.9	1	1	.052
1.040		60	45	3	0.19	1.54	1.83	5.7	6	7.4	1.2	17.7	0.9	1	1	.073
1.040		55	45	3	0.19	1.41	1.74	5.3	4	5	0.8	14.2	0.9	1	1	.052
1.080		60	45	2.7	0.38	2.78	1.83	5.7	6	7.4	1.2	18.9	0.9	1	0	.073
1.080		55	45	2.7	0.38	2.55	1.74	5.3	4	5	0.8	15.3	0.9	1	0	.052
1.100	1.3	60	45	2.5	0.48	3.21	1.83	5.7	6	7.4	1.2	19.4	0.9	0	1	.073
1.100	1.3	55	45	2.5	0.48	2.95	1.74	5.3	4	5	0.8	15.7	0.9	0	1	.052
1.150	0.96	60	45	2.2	0.71	4.24	1.83	5.7	6	7.4	1.2	20.4	0.9	1	0	.073
1.150	0.96	55	45	2.2	0.71	3.89	1.74	5.3	4	5	0.8	16.7	0.9	1	0	.052
1.340	0.48	55	45	1.25	2.20	6.81	0.87	5.3	6	7.4	1.2	21.6	0.9	0	1	.078
1.340	0.48	50	45	1.25	2.20	6.19	0.83	4.9	4	5	0.8	17.7	0.9	0	0	.056
1.500	0.32	60	45	1.25	1.20	4.05	0.91	5.7	6	7.4	1.2	19.3	0.9	0	1	.073
1.500	0.32	60	45	1.25	1.20	4.05	0.91	5.7	4	5	0.8	16.4	0.9	0	0	.048
														8	8	.063

Pow. of Counter A (W)	11.2			Had been 50 W. for 3x2 Atlas version
Wt. of Config. A (kg)	136	300	lbs	Had been 326 kg
Number of PMTs =	40			Had been 90
Pow. of Counter A (W)	11.2			Had been 60 W for 3x3 module version
Wt. of Config. B (kg)	141	310	lbs	Had been 400 kg
Number of PMTs =	40			Had been 108

Delta Version #5																
Version 5 has 2 counters per module as does #3.																
Top radiators are 55x42 (outer), 50x42 (inner); reduced size from #4																
Bottom radiators are 50x42 (outer), 45x42 (inner); reduced size from #4																
Now have 6 PMTs on outer counter, only 4 on inner																
Two radiator selections are indicated (A and B)																
						Rad	Rad	Box			Lin.	Tot.	Tot.			
Index	Tmin	x	y	z	density	Wt	Frame	Wt	#	Tube	Elec.	Cntr	Cntr			
Ref	GeV/n	cm	cm	cm	g/cm3	kg	kg	kg	tbs	Wt	Wt	Wt	Pow	A	B	T/B
1.025	3.35	55	42	3	0.12	0.82	1.69	5	6	7.4	1.2	16.2	0.9	1	1	.082
1.025	3.35	50	42	3	0.12	0.75	1.60	4.7	4	5	0.8	12.8	0.9	1	1	.059
1.040		55	42	3	0.19	1.32	1.69	5	6	7.4	1.2	16.7	0.9	1	1	.082
1.040		50	42	3	0.19	1.20	1.60	4.7	4	5	0.8	13.2	0.9	1	1	.059
1.080		50	42	2.7	0.38	2.16	1.60	4.7	6	7.4	1.2	17.1	0.9	1	0	.089
1.080		45	42	2.7	0.38	1.94	1.52	4.3	4	5	0.8	13.5	0.9	1	0	.064
1.100	1.3	50	42	2.5	0.48	2.50	1.60	4.7	6	7.4	1.2	17.4	0.9	0	1	.089
1.100	1.3	45	42	2.5	0.48	2.25	1.52	4.3	4	5	0.8	13.8	0.9	0	1	.064
1.150	0.96	50	42	2.2	0.71	3.30	1.60	4.7	6	7.4	1.2	18.2	0.9	1	0	.089
1.150	0.96	45	42	2.2	0.71	2.97	1.52	4.3	4	5	0.8	14.5	0.9	1	0	.064
1.340	0.48	50	42	1.25	2.20	5.78	0.80	4.7	6	7.4	1.2	19.9	0.9	0	0	.089
1.340	0.48	45	42	1.25	2.20	5.20	0.76	4.3	4	5	0.8	16.0	0.9	0	1	.064
1.500	0.32	50	42	1.25	1.20	3.15	0.80	4.7	6	7.4	1.2	17.3	0.9	0	1	.089
1.500	0.32	45	42	1.25	1.20	2.84	0.76	4.3	4	5	0.8	13.6	0.9	0	0	.064
						36	19	64		87	14	220	13	8	8	.075
Pow. of Counter A (W)					11.2			Had been 50 W. for 3x2 Atlas version								
Wt. of Config. A (kg)					124	274	lbs	Had been 326 kg								
Number of PMTs =					40			Had been 90								
Pow. of Counter A (W)					11.2			Had been 60 W for 3x3 module version								
Wt. of Config. B (kg)					126	276	lbs	Had been 400 kg								
Number of PMTs =					40			Had been 108								

Delta Version #6

Version 6 has only 3 modules (2 top, 1 bottom) with 2 counters per module.

Top radiators are 60x42 (outer), 55x42 (inner);

Bottom radiators are 80x42 (outer), 80x42 (inner).

On top have 6 PMTs on outer counter, 4 on inner

On bottom have 6 PMTs per counter inner, 8 PMTs per counter outer

Two radiator selections are indicated (A and B)

Index Ref	Tmin GeV/n	x cm	y cm	z cm	density g/cm3	Rad Wt kg	Rad Frame kg	Box Wt kg	# tbs	Tube Wt	Lin. Elec. Wt	Tot. Cntr Wt	Tot. Cntr Pow	A	B	T/B
1.025	3.35	90	42	3	0.12	1.35	2.30	7.6	8	9.9	1.6	22.8	1	1	1	.072
1.025	3.35	90	42	3	0.12	1.35	2.30	7.6	8	9.9	1.6	22.8	1	1	1	.072
1.055		55	42	3	0.26	1.82	1.69	5	6	7.4	1.2	17.2	0.9	1	0	.082
1.055		50	42	3	0.26	1.65	1.60	4.7	4	5	0.8	13.7	0.9	1	0	.059
1.080		50	42	2.7	0.38	2.16	1.60	4.7	6	7.4	1.2	17.1	0.9	0	0	.089
1.080		45	42	2.7	0.38	1.94	1.52	4.3	4	5	0.8	13.5	0.9	0	0	.064
1.100	1.3	55	42	2.5	0.48	2.75	1.69	5	6	7.4	1.2	18.1	0.9	0	1	.082
1.100	1.3	50	42	2.5	0.48	2.50	1.60	4.7	4	5	0.8	14.5	0.9	0	1	.059
1.150	0.96	55	42	2.2	0.71	3.63	1.69	5	6	7.4	1.2	19.0	0.9	1	0	.082
1.150	0.96	50	42	2.2	0.71	3.30	1.60	4.7	4	5	0.8	15.3	0.9	1	0	.059
1.340	0.48	50	42	1.25	2.20	5.78	0.80	4.7	6	7.4	1.2	19.9	0.9	0	0	.089
1.340	0.48	50	42	1.25	2.20	5.78	0.80	4.7	4	5	0.8	17.0	0.9	0	1	.059
1.500	0.32	55	42	1.25	1.20	3.47	0.84	5	6	7.4	1.2	18.0	0.9	0	1	.082
1.500	0.32	45	42	1.25	1.20	2.84	0.76	4.3	4	5	0.8	13.6	0.9	0	0	.064
						40	21	72		94	15	242	13	6	6	.072

Pow. of Counter A (W)	9.3			Had been 50 W. for 3x2 Atlas version
Wt. of Config. A (kg)	113	248	lbs	Had been 326 kg
Number of PMTs =	36			Had been 90
Pow. of Counter A (W)	9.3			Had been 60 W for 3x3 module version
Wt. of Config. B (kg)	115	253	lbs	Had been 400 kg
Number of PMTs =	36			Had been 108

Delta Version #7																
Version 7 has either 2 or 3 modules on top, each with 3 counters																
On the bottom the only counter is a pilot counter to identify charge																
Top radiators are 55x42 (outer); 50X42 (middle); 45x42 (inner)																
Bottom radiator is 90x42 with 8 PMTs																
On top have 4 PMTs on outer counter; 6 on middle; 4 on inner																
Selection A has two top modules; selection B has 3 top modules																
Index Ref	Tmin GeV/n	x cm	y cm	z cm	density g/cm3	Rad Wt kg	Rad Frame kg	Box Wt kg	# tbs	Tube Wt	Lin. Elec. Wt	Tot. Cntr Wt	Tot. Cntr Pow	A	B	T/B
1.025	3.35	50	42	3	0.12	0.75	1.60	4.7	6	7.4	1.2	15.7	0.9	0	1	.089
1.025	3.35	45	42	3	0.12	0.67	1.52	4.3	4	5	0.8	12.2	0.9	0	1	.064
1.055		50	42	3	0.26	1.65	1.60	4.7	6	7.4	1.2	16.6	0.9	1	1	.089
1.055		45	42	3	0.26	1.49	1.52	4.3	4	5	0.8	13.1	0.9	1	1	.064
1.080		50	42	2.7	0.38	2.16	1.60	4.7	6	7.4	1.2	17.1	0.9	0	0	.089
1.080		45	42	2.7	0.38	1.94	1.52	4.3	4	5	0.8	13.5	0.9	0	0	.064
1.100	1.3	50	42	2.5	0.48	2.50	1.60	4.7	6	7.4	1.2	17.4	0.9	0	0	.089
1.100	1.3	45	42	2.5	0.48	2.25	1.52	4.3	4	5	0.8	13.8	0.9	0	0	.064
1.150	0.96	50	42	2.2	0.71	3.30	1.60	4.7	6	7.4	1.2	18.2	0.9	1	1	.089
1.150	0.96	45	42	2.2	0.71	2.97	1.52	4.3	4	5	0.8	14.5	0.9	1	1	.064
1.340	0.48	50	42	1.25	2.20	5.78	0.80	4.7	6	7.4	1.2	19.9	0.9	0	0	.089
1.340	0.48	55	42	1.25	2.20	6.35	0.84	5	4	5	0.8	18.0	0.9	0	0	.055
1.500	0.32	55	42	1.25	1.20	3.47	0.84	5	4	5	0.8	15.1	0.9	4	3	.055
1.500	0.32	99	42	1.25	1.20	6.24	1.23	8.3	8	9.9	1.6	27.3	1	0	1	.066
						42	19	68		89	14	232	13	8	10	.073
Pow. of Counter A (W)					10.9			Had been 50 W. for 3x2 Atlas version								
Wt. of Config. A (kg)					125	274	lbs	Had been 326 kg								
Number of PMTs =					36			Had been 90								
Pow. of Counter A (W)					13.4			Had been 60 W for 3x3 module version								
Wt. of Config. B (kg)					166	364	lbs	Had been 400 kg								
Number of PMTs =					50			Had been 108								

Delta Version #8

Version 8 has 2 modules on top, each with 3 counters

On the bottom the only counter is a pilot counter to identify charge

Top radiators are 44x42 (outer); 42X42 (middle); 42x42 (inner)

Bottom radiator is 90x42 with 4 PMTs

On top have 8 PMTs on outer counter; 4 on middle; 4 on inner

Selection A has two top modules; selection B has 1 top modules

Index Ref	Tmin GeV/n	x cm	y cm	z cm	density g/cm3	Rad Wt kg	Rad Frame kg	Box Wt kg	# tbs	Tube Wt	Lin. Elec. Wt	Tot. Cntr Wt	Tot. Cntr Pow	A	B	T/B
1.025	3.35	42	42	3	0.12	0.63	1.46	4.1	4	5	0.8	11.9	0.9	1	1	.068
1.025	3.35	42	42	3	0.12	0.63	1.46	4.1	4	5	0.8	11.9	0.9	1	1	.068
1.055		50	42	3	0.26	1.65	1.60	4.7	6	7.4	1.2	16.6	0.9	0	0	.089
1.055		45	42	3	0.26	1.49	1.52	4.3	4	5	0.8	13.1	0.9	0	0	.064
1.080		50	42	2.7	0.38	2.16	1.60	4.7	6	7.4	1.2	17.1	0.9	0	0	.089
1.080		45	42	2.7	0.38	1.94	1.52	4.3	4	5	0.8	13.5	0.9	0	0	.064
1.100	1.3	42	42	2.5	0.48	2.10	1.46	4.1	4	5	0.8	13.4	0.9	1	1	.068
1.100	1.3	42	42	2.5	0.48	2.10	1.46	4.1	4	5	0.8	13.4	0.9	1	1	.068
1.150	0.96	50	42	2.2	0.71	3.30	1.60	4.7	6	7.4	1.2	18.2	0.9	0	0	.089
1.150	0.96	45	42	2.2	0.71	2.97	1.52	4.3	4	5	0.8	14.5	0.9	0	0	.064
1.340	0.48	50	42	1.25	2.20	5.78	0.80	4.7	6	7.4	1.2	19.9	0.9	0	0	.089
1.340	0.48	55	42	1.25	2.20	6.35	0.84	5	4	5	0.8	18.0	0.9	0	0	.055
1.500	0.32	44	42	1.25	1.20	2.77	0.75	4.2	4	5	0.8	13.5	0.9	3	0	.065
1.500	0.32	90	42	1.25	1.20	5.67	1.15	7.6	8	9.9	1.6	25.9	1	0	2	.072
						40	19	65		84	14	221	13	7	6	.072

Pow. of Counter A (W)	9.7			Had been 50 W. for 3x2 Atlas version
Wt. of Config. A (kg)	93	204	lbs	Had been 326 kg
Number of PMTs =	32			Had been 90
Pow. of Counter B (W)	9.0			Had been 60 W for 3x3 module version
Wt. of Config. B (kg)	104	229	lbs	Had been 400 kg
Number of PMTs =	32			Had been 108

Delta Version #9

						Rad	Rad	Box			Lin.	Tot.	Tot.			
Index	Tmin	x	y	z	density	Wt	Frame	Wt	#	Tube	Elec.	Cntr	Cntr			
Ref	GeV/n	cm	cm	cm	g/cm3	kg	kg	kg	tbs	Wt	Wt	Wt	Pow	A	B	T/B
1.025	3.35	50	42	3	0.12	0.75	1.60	4.7	6	7.4	1.2	15.7	0.9	0	0	.089
1.025	3.35	45	42	3	0.12	0.67	1.52	4.3	4	5	0.8	12.2	0.9	0	0	.064
1.055	2	54	54	3	0.26	2.29	1.88	6	6	7.4	1.2	18.8	0.9	2	0	.069
1.055	2	45	45	3	0.26	1.59	1.57	4.5	4	5	0.8	13.4	0.9	0	2	.061
1.080		50	42	2.7	0.38	2.16	1.60	4.7	6	7.4	1.2	17.1	0.9	0	0	.089
1.080		45	42	2.7	0.38	1.94	1.52	4.3	4	5	0.8	13.5	0.9	0	0	.064
1.100	1.3	50	42	2.5	0.48	2.50	1.60	4.7	6	7.4	1.2	17.4	0.9	0	0	.089
1.100	1.3	45	42	2.5	0.48	2.25	1.52	4.3	4	5	0.8	13.8	0.9	0	0	.064
1.150	0.96	45	45	2.2	0.71	3.18	1.57	4.5	4	5	0.8	15.0	0.9	2	0	.061
1.150	0.96	45	45	2.2	0.71	3.18	1.57	4.5	4	5	0.8	15.0	0.9	0	0	.061
1.340	0.48	65	65	1.25	2.20	####	1.13	8.1	6	7.4	1.2	29.5	0.9	0	0	.051
1.340	0.48	45	45	1.25	2.20	5.57	0.78	4.5	4	5	0.8	16.6	0.9	0	0	.061
1.500	0.32	65	65	1.25	1.20	6.34	1.13	8.1	6	7.4	1.2	24.2	0.9	2	0	.051
1.500	0.32	50	50	1.25	1.20	3.75	0.87	5.3	4	5	0.8	15.7	0.9	0	2	.052
						48	20	73		84	14	238	13	6	4	.066

Pow. of Counter A (W)	9.0			Had been 50 W. for 3x2 Atlas version
Wt. of Config. A (kg)	118	260	lbs	Had been 326 kg
Number of PMTs =	32			Had been 90
Pow. of Counter A (W)	6.3			Had been 60 W for 3x3 module version
Wt. of Config. B (kg)	59	130	lbs	Had been 400 kg
Number of PMTs =	16			Had been 108

Table 2

											RAM
			DELTA CLASS LISAs								3.24.92
Item											
#	**Item**	**Notes**	**Atlas**	**Del-1**	**Del-4**	**Del-5**	**Del-6**	**Del-7**	**Del-8**	**Del-9**	**Del-10**
1	# Modules		5	5	4	4	3	3	3	2	2
2	C-counters/mod		3	3	2	2	2	3,3,1	3,3,1	3	3
3	tot.# PMTs		90	90	40	40	36	36	32	32	16
4	C- Width		42-58	42-58	45	42	42	42	42	45-65	44-50
5	Cerenkov Wt.	1	326	308	136	124	113	125	104	118	59
6	TOF Area	2	19600	19600	12032	10032	9064	10032	8096	12800	7200
7	# TOF PMTs	3	40	40	24	24	22	24	24	16	12
8	TOF Wt.	4	68	68	45	41	37	39	33	47	30
9	Hodo Separation		200	200	160	160	160	160	160	150	150
10	Hodo Area (m2)	5	10.44	10.44	5.40	4.20	4.12	4.20	3.78	1.26	1.00
11	# Hodo Planes		8xy	8xy	7x,5y	5xy	5xy	5xy	8xy	4xy	4xy
12	Hodo Detect (kg)	6	95	95	56	47	47	47	44	25	23
13	Hodo Struct. (kg)	7	98	98	59	50	50	50	53	28	26
14	Hodo Shield (kg)	8	51	51	26	19	19	19	17	6	5
15	Pow. Supp. Wt.	9	*30*	*26*	*18*	*17*	*16*	*16*	*10*	*14*	*12*
16	Cent. Proc. Wt.	10	*15*	*5*	*5*	*5*	*5*	*5*	*5*	*5*	*7*
17	Tot	11	45	31	23	22	21	21	15	19	19
18	Outer Trusses	12	100	94	45	41	38	41	34	41	22
19	Structure	13	82	75	39	34	32	34	30	28	18
20	Total mass (Kg)	14	865	820	430	379	356	377	330	312	202
21	Total lbs		1903	1803	947	833	782	828	726	685	444
22	Struc./Det. Ratio		0.62	0.63	0.65	0.62	0.63	0.62	0.69	0.49	0.54
23	Cerenkov Power	15	63	24	11	11	9	9	10	9	6
24	TOF power	16	50	25	18	16	15	16	14	18	13
25	Hodo Power	17	97	97	58	49	49	49	46	27	25
26	Cent. Processor	18	75	10	10	10	10	10	10	10	10
27	Unreg. Power	20	285	156	97	86	82	84	80	64	54
28	Ineffic. (25%)		95	52	32	29	27	28	27	21	18
29	Total Power	21	380	208	129	115	110	112	106	86	72

Notes:

1) Calculated in detail for all options

2) Active scintillator area required to cover the C modules

3) Generally assume two PMTs for each ~20 cm of width

4) Scaled by TOF area + 8 kg; based on Wiedenbeck memo of 2/12/91

5) Total required active area of fibers

6) Scaled from Atlas version using M = 15 + 80(A2/A1); A2, A1 are active fiber areas

7) Scaled from Atlas; proportional to active fiber area

8) Scaled from Atlas; proportional to active fiber area (Can we drop this now?)

9) Assumed to be 2/3 of the 45 kg devoted to the Atlas central control unit.
For others scale by P = 5 kg + 25 kg*(Items 33-36)/185

10) Assumed to be 15 for Atlas; taken to be 7 for Delta versions

11) Given somewhere as 45 on Atlas; summed from items #15 +#16 for Delta

12) Scaled by taking 25% of the Cerenkov + TOF weights

13) Scaled by taking 10% of everything else; including outer trusses

14) Sum of all mass above

15) Detailed estimates, including the use of VLSI for Delta versions
I don't understand the Atlas # of 63 W.; I think it should be ~50

16) Crude estimate scaled by TOF area + 6 watts (see 1/4/91 MEW memo);
includes some VLSI in Delta versions

17) Crude estimate scaled by Hodo area + 17 watts

18) I don't understand the Atlas number of 75 W; 10 W should be more than adequate
unless the central processor is doing much more than I understand.

19) Sum of above numbers

20) The Atlas report lists 380 W. for LISA; R. Streitmatter gave me the above breakdown
for this (items 21-25)

Table 3

Cosmic Ray Isotope Yields

	Space Station	Atlas	Delta
MDR (TV)	3.2	2.4	1.3
Geometry Factor (m2sr)	0.09	0.03	0.025
Inclination	28.5 deg	57 deg	57 deg
Rel. Yield 1 to 3 GeV/nuc	1	5.5	4.6
Rel. Yield <1 GeV/nuc	0	3.6	3

Figure Captions

Figure 1: The Space Station and Atlas versions of Astromag

Figure 2: Scematic illustration of 5 possible configurations for a Delta-class version of the LISA experiment. The following abbreviations are used: P = Pilot-425 radiator; A1, A2, etc = aerogel radiators of various indices of refraction; CM = Cherenkov mass; CP = Cherenkov power; HL = hodoscope length; PMT = # of Cherenkov PMTs; TOFL = TOF length.

Figure 3: Larger size version of Delta version #5 (see Figure 2).

Figure 4: Delta-class Version #6 of the LISA experiment.

Figure 5: Delta-class Version #7 of the LISA experiment.

Figure 6: Orbit averaged energy spectra for a typical element such as oxygen.

Figure 7: Maximum energy to which heavy isotopes can be resolved as a function of the MDR of the spectrometer. It is assumed that the spectrometer contributes less than 0.2 amu to the total mass resolution.

Figure 8: Expected mass resolution for Si isotopes in a small version of the LISA experiment compatible with a Delta launch vehicle. The characteristics of the Cherenkov radiators are listed.

Figure 9: Expected mass resolution for Fe isotopes in a small version of the LISA experiment compatible with a Delta launch vehicle. The characteristics of the Cherenkov radiators are listed.

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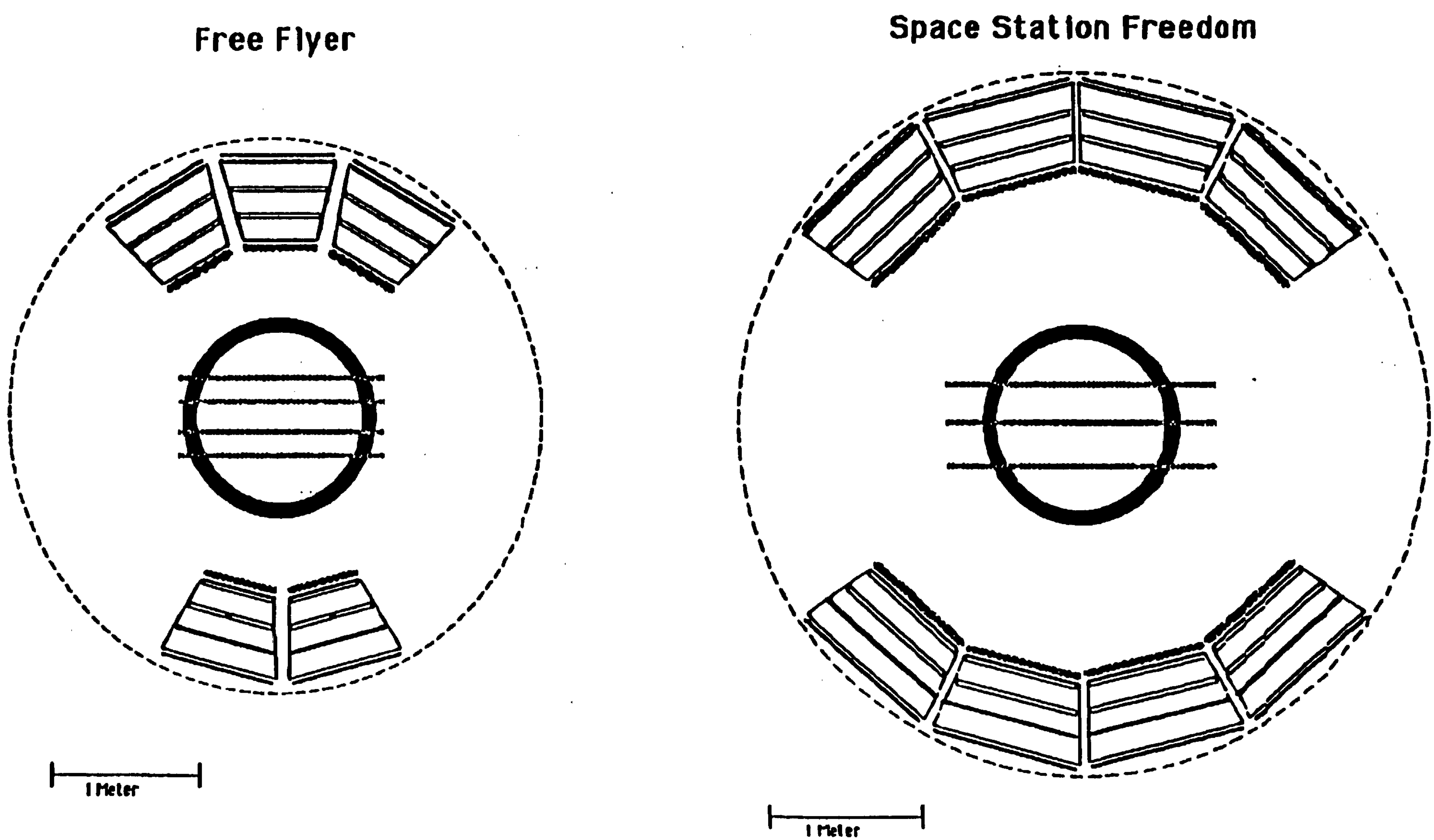


Figure 1

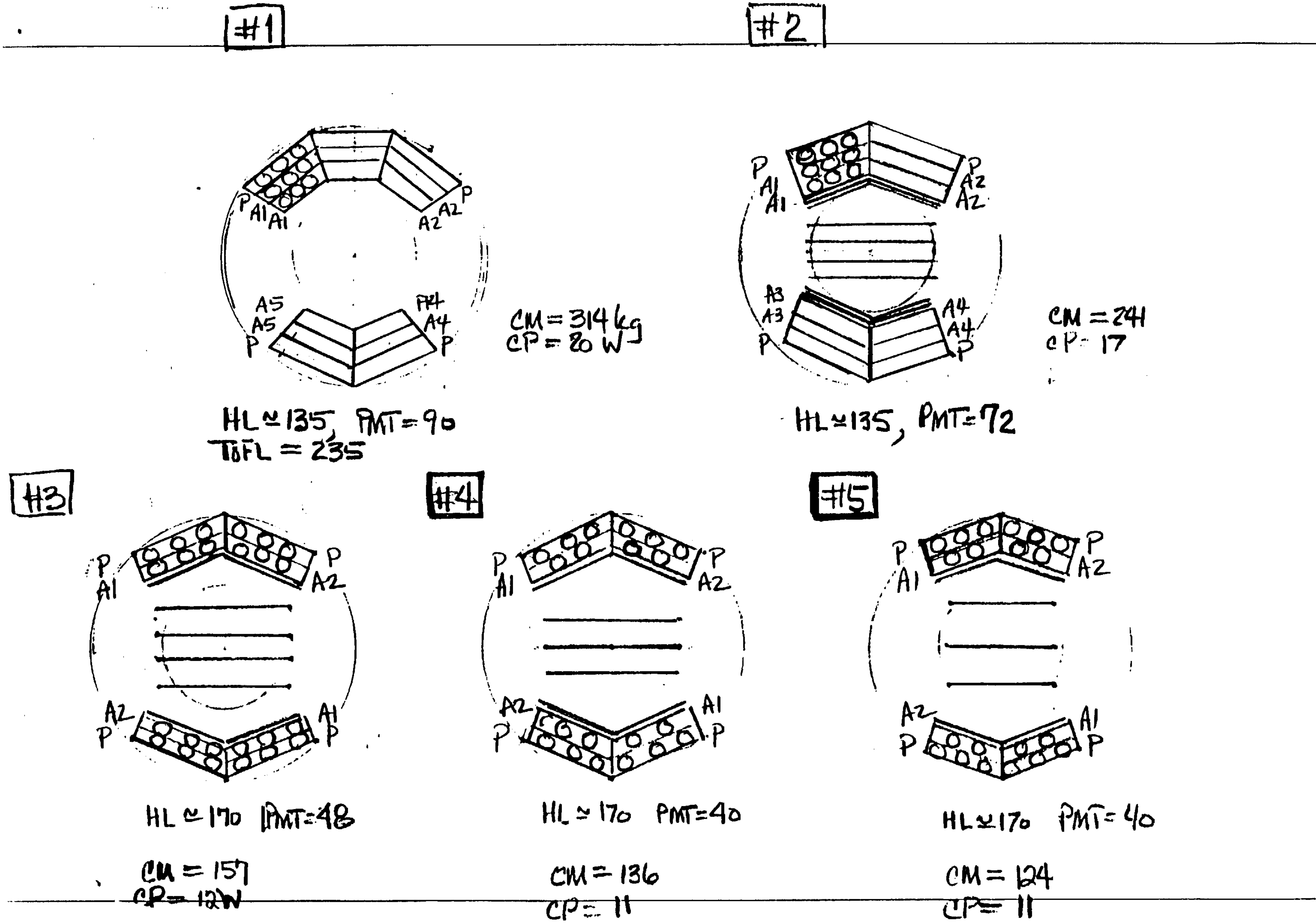

#1
P A1 A1
A2 A2 P
A5 A5 P
A4 A4 P
CM = 314 kg
CP = 80 W
HL ≃ 135, PMT = 90
TOFL = 235
#2
P A1 A1
P A2 A2
A3 A3 P
A4 A4 P
CM = 241
CP = 17
HL ≃ 135, PMT = 72
#3
P A1
P A2
A2 P
A1 P
HL ≃ 170 PMT = 48
CM = 157
CP = 12W
#4
P A1
P A2
A2 P
A1 P
HL ≃ 170 PMT = 40
CM = 136
CP = 11
#5
P A1
P A2
A2 P
A1 P
HL ≃ 170 PMT = 40
CM = 124
CP = 11

Figure 2

Delta Version
#5

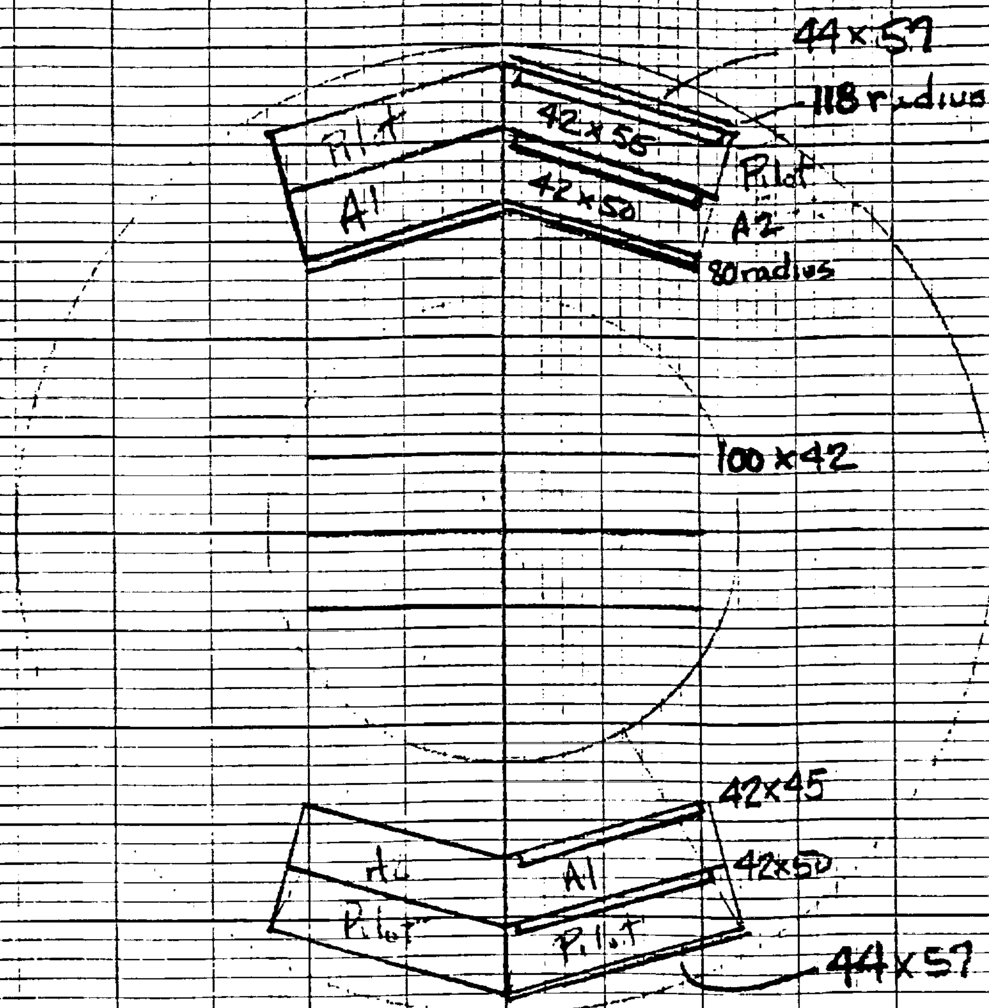


Figure 3

46 0782
K+E 10 X 10 TO THE INCH • 7 X 10 INCHES
KEUFFEL & ESSER CO. MADE IN U.S.A.

Delta Version
#6

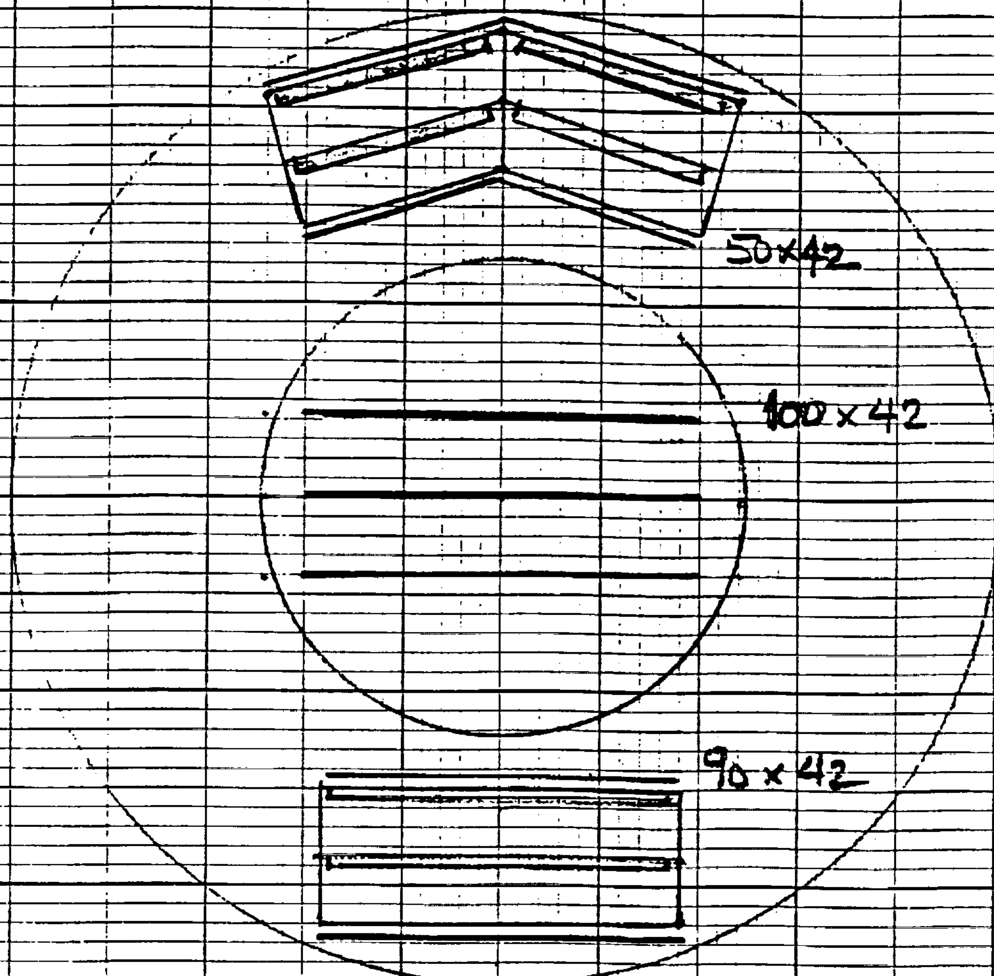


Figure 4

46 0782
K+E 10 X 10 TO THE INCH • 7 X 10 INCHES
KEUFFEL & ESSER CO. MADE IN U.S.A.

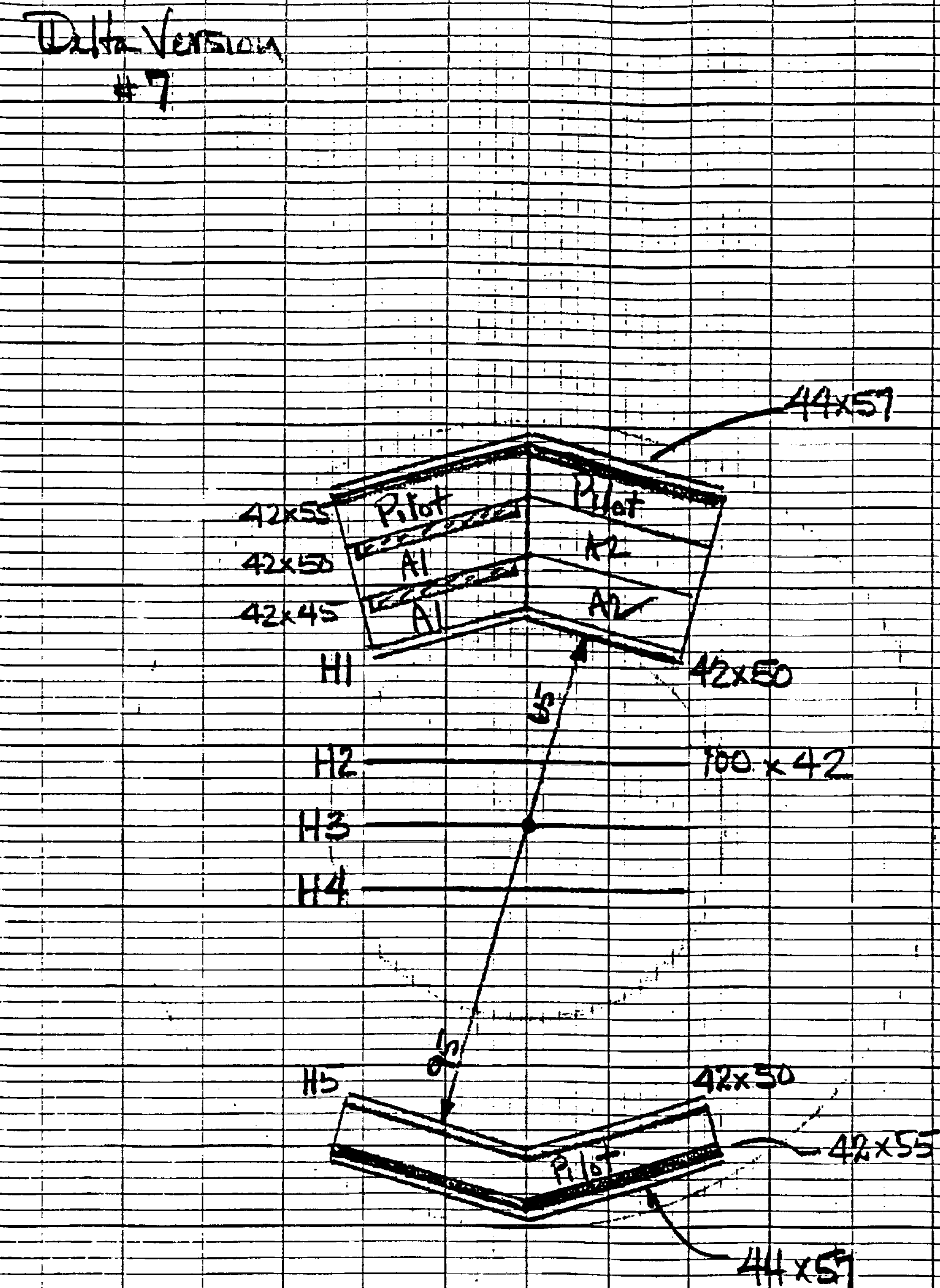
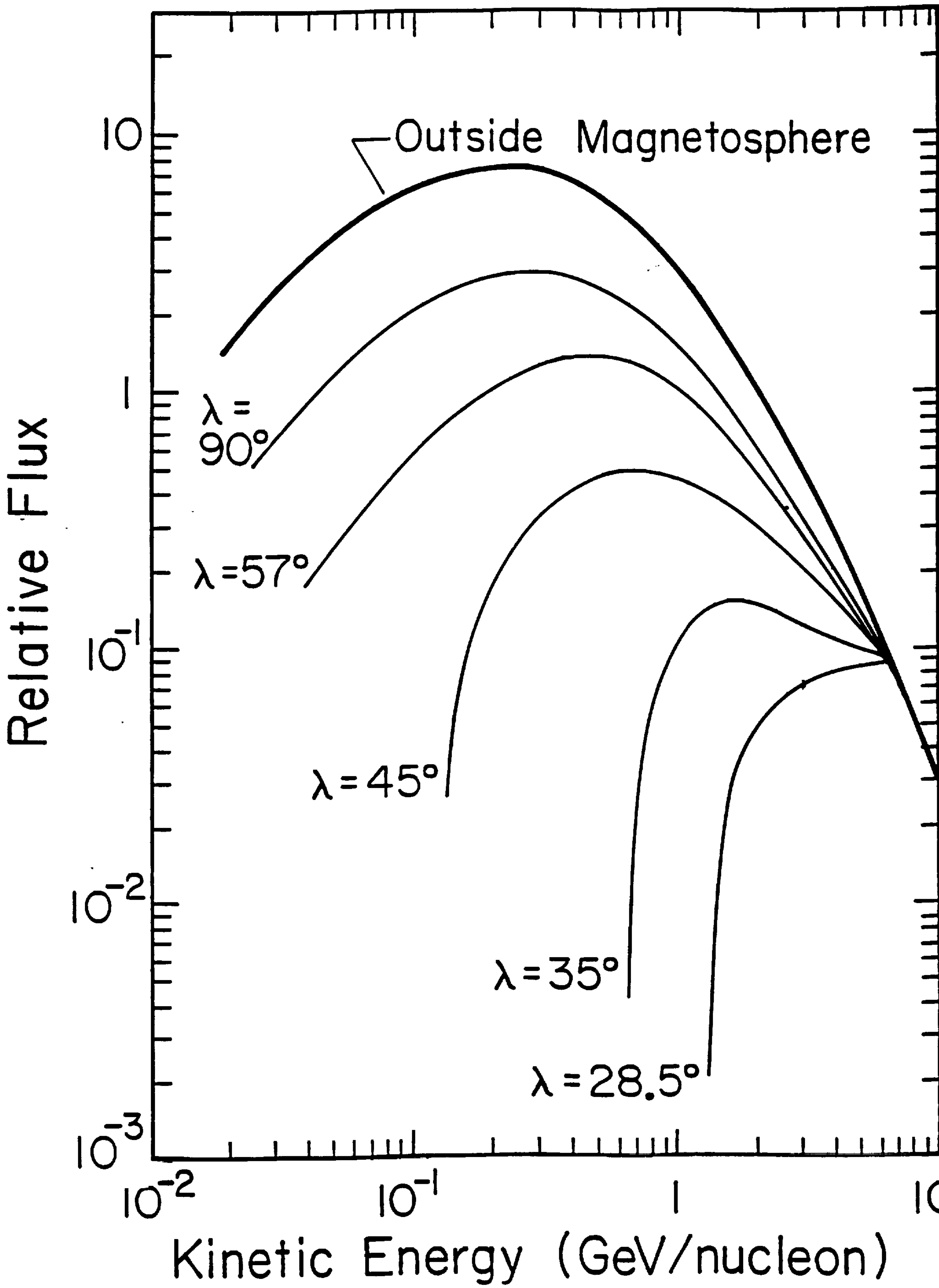


Figure 5

46 0782

K+E 10 X 10 TO THE INCH KEUFFEL & ESSER CO.



Outside Magnetosphere
λ = 90°
λ = 57°
λ = 45°
λ = 35°
λ = 28.5°
Relative Flux
10
1
10^{-1}
10^{-2}
10^{-3}
10^{-2}
10^{-1}
1
10
Kinetic Energy (GeV/nucleon)

Figure 6

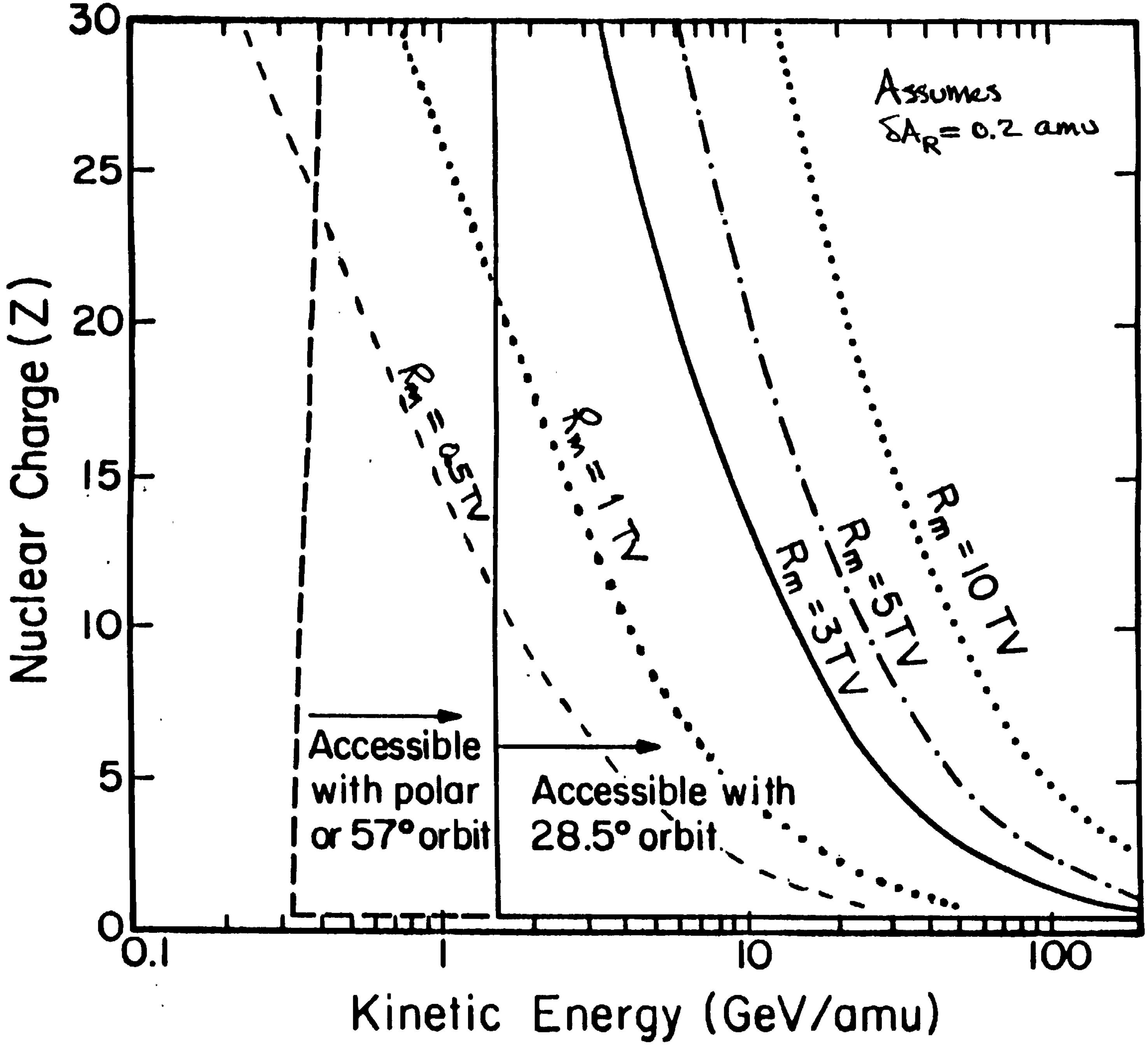

Nuclear Charge (Z)
Kinetic Energy (GeV/amu)
Assumes
δA_R = 0.2 amu
R_m = 0.5 TV
R_m = 1 TV
R_m = 3 TV
R_m = 5 TV
R_m = 10 TV
Accessible with polar or 57° orbit
Accessible with 28.5° orbit

Figure 7

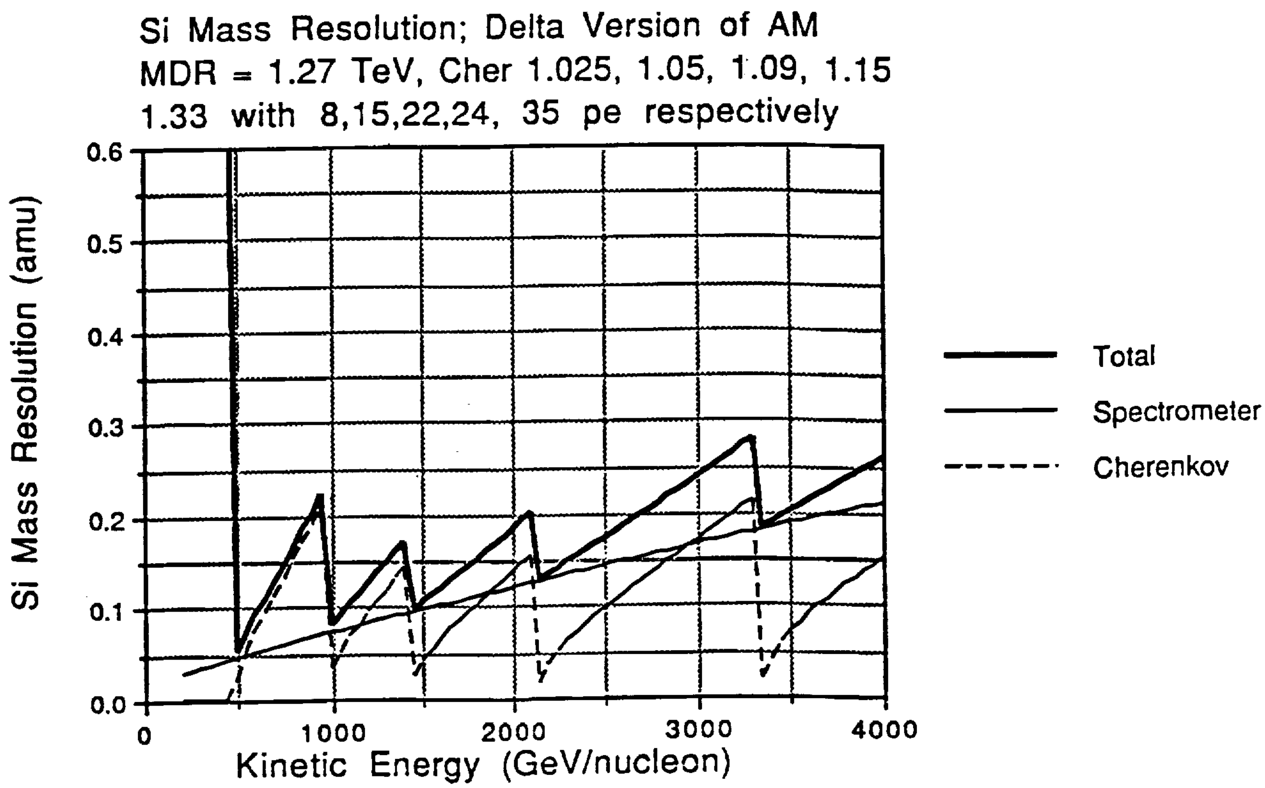

Si Mass Resolution; Delta Version of AM
MDR = 1.27 TeV, Cher 1.025, 1.05, 1.09, 1.15
1.33 with 8,15,22,24, 35 pe respectively
Si Mass Resolution (amu)
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0
1000
2000
3000
4000
Kinetic Energy (GeV/nucleon)
Total
Spectrometer
Cherenkov

Figure 8

Attachment #1

California Institute of Technology
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10/26/92

To: The LISA Astromag Team
From: Dick Mewaldt RAM
Subject: Possible Delta-Class Astromag Designs

I have identified some possible designs for LISA that I estimate will require only about 800 lbs to implement and which may therefore be compatable with launch on a Delta. Although they all require compromises of energy coverage and/or geometry factor, it is possible that they may later be expanded some if we can be more clever in our use of resources, or if additional resources become available. I have made careful evaluations of the requirements of the Cerenkov subsystem for these designs, and have down-sized this system by a factor of 2 to 3 over our Atlas design. I think that the next step is to obtain more accurate estimates for the other subsystems, particularly in the area of structure (see discussion below). We should also see to what extent these designs meet our resolution and yield requirements.

Summary of Possible Designs

Figures 1 to 4 sketch some possible approaches that represent the gradual steps that I took in reducing the mass. The choice of radiators that go into the modules does not have much effect on the required resources, but in order to achieve the goals of ~750-800 lbs I have had to severely limit the number of Cerenkov modules. This leaves several choices: getting away from redundant Cerenkov measurements; omitting the Pilot counters and relying on the TOF scintillators for charge identification, or severely restricting the number of energy ranges. The basic design I am left with allows for all of these possibilities for similar requirements on the TOF and Hodoscope subsystems. Table 1 summarizes my estimates of the mass and power requirements.

Of the designs shown, numbers 5, 6, and 7 (see Figures 2, 3, 4) are each ~800 lbs. When I was at our meeting in College Park I was favoring #5, which was to have 8 different aerogel counters (of 4 indices, A1 to A4 in Figure 1), but would use only the dE/dx-Aerogel, or the dE/dX-TOF to measure charge, where dE/dx comes from the scintillator. I now think that this approach probably will not give adequate charge resolution, and I am again favoring putting the Pilot Cerenkov back in to measure charge (and do isotopes below 1 GeV/nuc). To do this I am reducing the number of aerogel counters so that there are only two indices (A1 and A2 in Figure 1), each with two counters. (I still think redundant velocity measurements are important). In any case, the requirements for the hodoscope and TOF are about the same. One possibility that should be considered is a Pilot counter that uses total internal rerflection instead of a white box, so that it can be done for less mass and space.

Version #6 does not adapt itself very well to using the Pilot radiators and I am not now considering it. It originally was to have three modules (2 small and 1 big) featuring three separate indices of aerogel.

Version 7 is the one I now favor. It has only a Pilot counter and TOF at the bottom. There are two indices of aerogel which might be tuned to have thresholds at perhaps ~1 and ~2.5 GeV/nuc. We would also get isotopes from the Pilot counters. Although the design is asymmetric, it seems to me to have all the requirements.

Each of versions 1 to 7 fits into a 2.5 m radius. In versions 5, 6, and 7 the hodoscope separation is about 160 cm and the TOF separation is about 235 cm. The width of the hodoscope and TOF active area in these latter three cases is reduced to 42 cm. In this way I think our overall width will be <0.9 m. I was forced to reduce the hodoscope to 5 layers to meet the weight requirements. We might want to re-examine some of these trade-offs once we have better numbers. If more mass becomes available we can consider adding another module (and energy range) on top, or we can add more hodoscope layers, or PMTs, or increase the counter areas, etc.

Weight and Power Estimates

For each of the seven designs I have evaluated in detail the resources required for the Cerenkov subsystem. I then attempted to scale the mass and power for the other subsystems to see if I was in the ball-park. The assumed scaling relations are documented in the notes to Table 1.

Cerenkov Subsystem

The mass and power estimates in Table 1 are based on the following changes from our Atlas design.

1) We are now baselining VLSI circuitry for the PHA and discriminator chains. Much of the work required to implement these designs has been financed by the ACE project; we hope to adapt these designs to the analysis of photomultiplier (PMT) signals within our SR&T effort over the next year or two. We expect to achieve a 12-bit ADC chain that will require only ~0.02 W and 0.04 kg (including the weight of the board). With additional work we may also be able to implement the designs required for TOF circuitry in VLSI. The resulting gains will reduce the mass and power required by LISA, and should also lead to savings in other areas such as power supplies and solar panels.

2) The weight of mounted aerogels ~50x50 cm2 in area and their frames and potting material has been measured accurately. This design survived a balloon launch and landing.

3) We are now base-lining that the frames that mount the aerogel radiators will fabricated from composite materials; leading to a 40% savings over the use of aluminum.

Suggestions for Possible Improvements in other Subsystems

Structure: The ratio of inactive "structure" to "detector + electronics" in our Atlas design is ~0.6; which seems very conservative to me. I have maintained this ratio in my estimates for these Delta-class designs (see Table 1), but would like to see more mass freed up for the detectors. Perhaps we can achieve some savings in this area through the use of composite materials.

Central Processor and Power Supplies: The estimated mass and power for this seems very high - much more than we can afford, but I have no visibility into where it is going. I think that <10 kg and <10 W should be more than adequate for the central processor. As an example, In the CRIS experiment on ACE we are doing all of the on-board processing required for six planes of a SOFT hodoscope and four silicon stacks (with 14 ADCs and 20 discriminators) for <5 W and <5 kg. CRIS is of comparable complexity to LISA. We have similar requirements for on-board processing of the SOFT data, and both experiments must minimize the amount of pulseheight data by transmitting pulseheights only that from those modules that are triggered. The event rates are also comparable, with CRIS having the higher event rate because it has no geomagnetic cutoff. This subsystem also has the functions of accumulating rates, formatting (packetizing) the data, and handling commands, housekeeping etc. The DPU on SAMPEX (designed and built by Aerospace Corp.) handles all of these functions for four different instruments for a total of 6 watts and 3 kg. We need to separate out the processing and power supply functions, and look critically at the requirements for each.

The TOF System: Since the requirements of this system depend on the amount of area covered it is difficult to gain much from the detector system except by reducing the size. However, significant savings would seem to be possible in the weight and power requirements for the electronics by going to VLSI designs. I have already included some savings by assuming that the ADC and discriminator circuits from ACE can be adapted to this system. It is likely that other circuits can also be incorporated into VLSI designs.

The SOFT Hodoscope: It appears to me that the only way to get sufficient savings from this subsystem (once the overall area has been reduced) is to reduce the number of planes from 8xy to perhaps 5x and 5y. This needs to be looked at more closely taking into account the MDR that will result. Other combinations such as 6x and 4y should also be considered, and the fiber thickness should be examined. I certainly hope that the light-tite shield and registration system can be eliminated, but have retained the scaled-down mass here just in case. If still required, maybe the thickness of the light shield can be reduced now that it is smaller. Maybe it can be made from a thin plastic. The resouces required for the camera system and other electronics should be re-evaluated based on the work that has recently been done for ACE. The fact that SOFT will fly on ACE should allow us to carry somewhat less contingency for this system, once we know what it actually takes.

Overall, I think we should have the goal of coming in under my scaled estimates (Table 1) so that we can add more science. It would be very helpful if each subsystem developed simple algorithms to allow the scaling of mass and power by area, number of PMTs or cameras, or some related parameters. Then we can more easily examine the tradeoffs.

									RAM	
			DELTA CLASS LISAs					10.27.92		
Item #	Item	Notes	Atlas	Del-1	Del-2	Del-3	Del-4	Del-5	Del-6	Del-7
1	# Modules		5	5	4	4	4	4	3	3
2	C-counters/mod		3	3	3	2	2	2	2	3,3,1
3	tot.# PMTs		90	90	72	48	40	40	36	36
4	C- Width		42-58	42-58	50	50	45	42	42	42
5	Cerenkov Wt.	1	326	308	226	157	136	124	113	125
6	TOF Area	2	19600	19600	15120	14352	12032	10032	9064	10032
7	# TOF PMTs	3	40	40	32	32	24	24	22	24
8	TOF Wt.	4	68	68	54	52	45	41	37	39
9	Hodo Separation		200	200	125	160	160	160	160	160
10	Hodo Area (m2)	5	10.44	10.44	7.70	5.50	5.40	4.20	4.12	4.20
11	# Hodo Planes		8xy	8xy	8x,6y	8x,6y	7x,5y	5xy	5xy	5xy
12	Hodo Detect (kg)	6	95	95	74	57	56	47	47	47
13	Hodo Struct. (kg)	7	98	98	77	60	59	50	50	50
14	Hodo Shield (kg)	8	51	51	38	27	26	19	19	19
15	Pow. Supp. Wt.	9	*30*	*26*	*22*	*19*	*18*	*17*	*16*	*16*
16	Cent. Proc. Wt.	10	*15*	*7*	*7*	*7*	*7*	*7*	*7*	*7*
17	Tot	11	45	33	29	26	25	24	23	23
18	Outer Trusses	12	100	94	70	52	45	41	38	41
19	Structure	13	82	75	57	43	39	35	33	34
20	Total mass (Kg)	14	865	822	624	474	433	381	358	379
21	Total lbs		1903	1808	1374	1043	952	838	787	833
22	Struc./Det. Ratio		0.62	0.63	0.63	0.62	0.65	0.62	0.63	0.62
23	Cerenkov Power	15	63	24	17	12	11	11	9	9
24	TOF power	16	50	25	21	20	18	16	15	15
25	Hodo Power	17	97	97	76	59	58	49	49	49
26	Cent. Processor	18	75	10	10	10	10	10	10	10
27	Unreg. Power	20	285	156	124	101	97	86	83	83
28	Ineffic. (25%)		95	52	41	34	32	29	28	28
29	Total Power	21	380	208	165	135	129	115	110	111

	Notes:
	1) Calculated in detail for all options
	2) Active scintillator area required to cover the C modules
	3) Generally assume two PMTs for each ~20 cm of width
	4) Scaled by TOF area + 8 kg; based on Wiedenbeck memo of 2/12/91
	5) Total required active area of fibers
	6) Scaled from Atlas version using M = 15 + 80(A2/A1); A2, A1 are active fiber areas
	7) Scaled from Atlas; proportional to active fiber area
	8) Scaled from Atlas; proportional to active fiber area (Can we drop this now?)
	9) Assumed to be 2/3 of the 45 kg devoted to the Atlas central control unit.
	For others scale by P = 5 kg + 25 kg*(Items 33-36)/185
	10) Assumed to be 15 for Atlas; taken to be 7 for Delta versions
	11) Given somewhere as 45 on Atlas; summed from items #15 +#16 for Delta
	12) Scaled by taking 25% of the Cerenkov + TOF weights
	13) Scaled by taking 10% of everything else; including outer trusses
	14) Sum of all mass above
	15) Detailed estimates, including the use of VLSI for Delta versions
	I don't understand the Atlas # of 63 W.; I think it should be ~50
	16) Crude estimate scaled by TOF area + 6 watts (see 1/4/91 MEW memo);
	includes some VLSI in Delta versions
	17) Crude estimate scaled by Hodo area + 17 watts
	18) I don't understand the Atlas number of 75 W; 10 W should be more than adequate
	unless the central processor is doing much more than I understand.
	19) Sum of above numbers
	20) The Atlas report lists 380 W. for LISA; R. Streitmatter gave me the above breakdown
	for this (items 21-25)

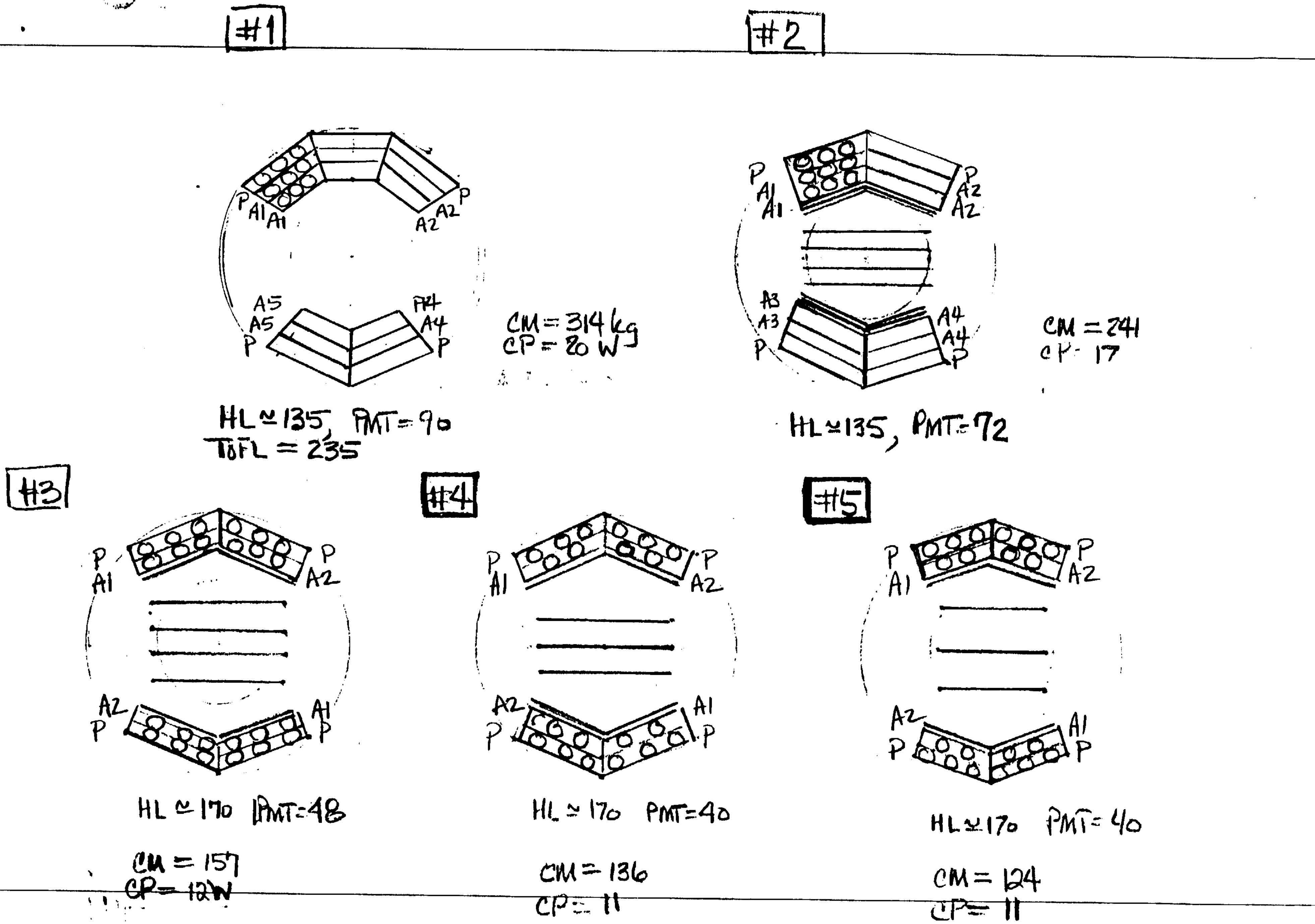
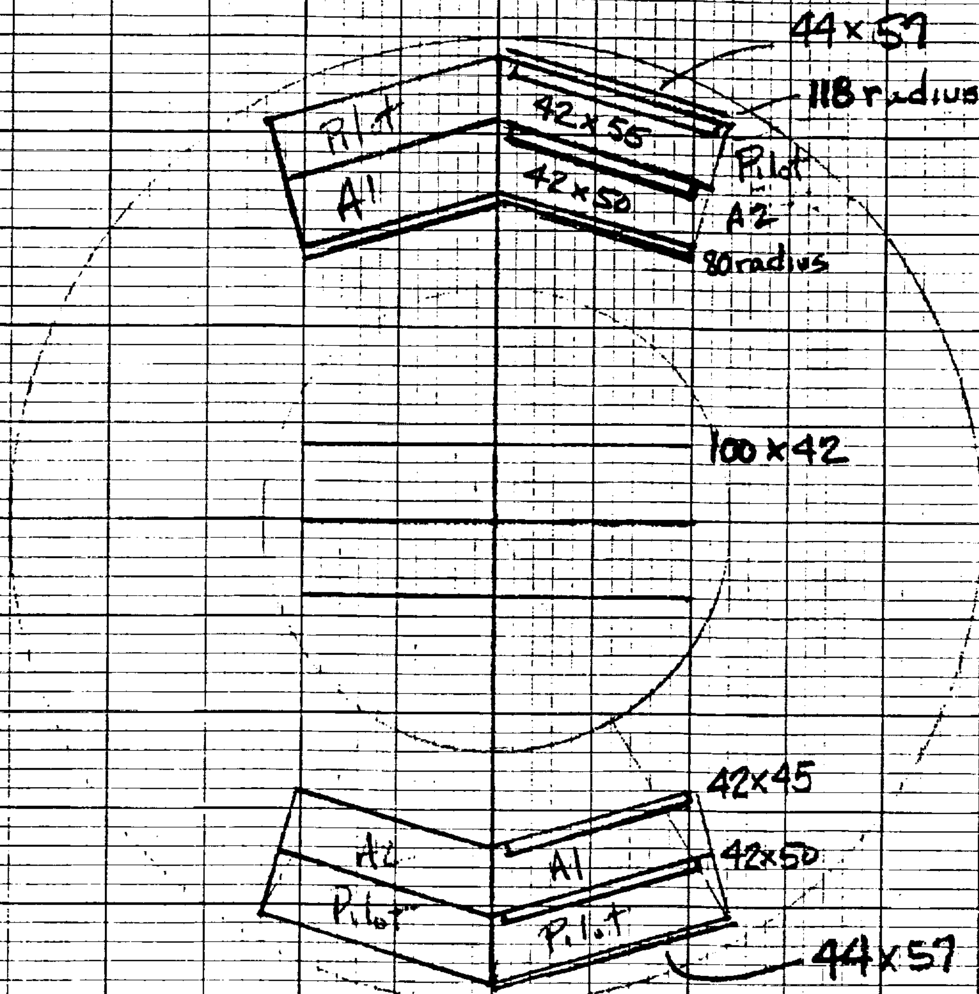

#1
P A1 A1
A2 A2 P
A5 A5 P
A4 A4 P
CM = 314 kg
CP = 80 W
HL ≃ 135, PMT = 90
TOFL = 235
#2
P A1 A1
P A2 A2
A3 A3 P
A4 A4 P
CM = 241
CP = 17
HL ≃ 135, PMT = 72
#3
P A1
P A2
A2 P
A1 P
HL ≃ 170 PMT = 48
CM = 157
CP = 12W
#4
P A1
P A2
A2 P
A1 P
HL ≃ 170 PMT = 40
CM = 136
CP = 11
#5
P A1
P A2
A2 P
A1 P
HL ≃ 170 PMT = 40
CM = 124
CP = 11

Fig. 1

Delta Version
#5



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Delta Version

#6

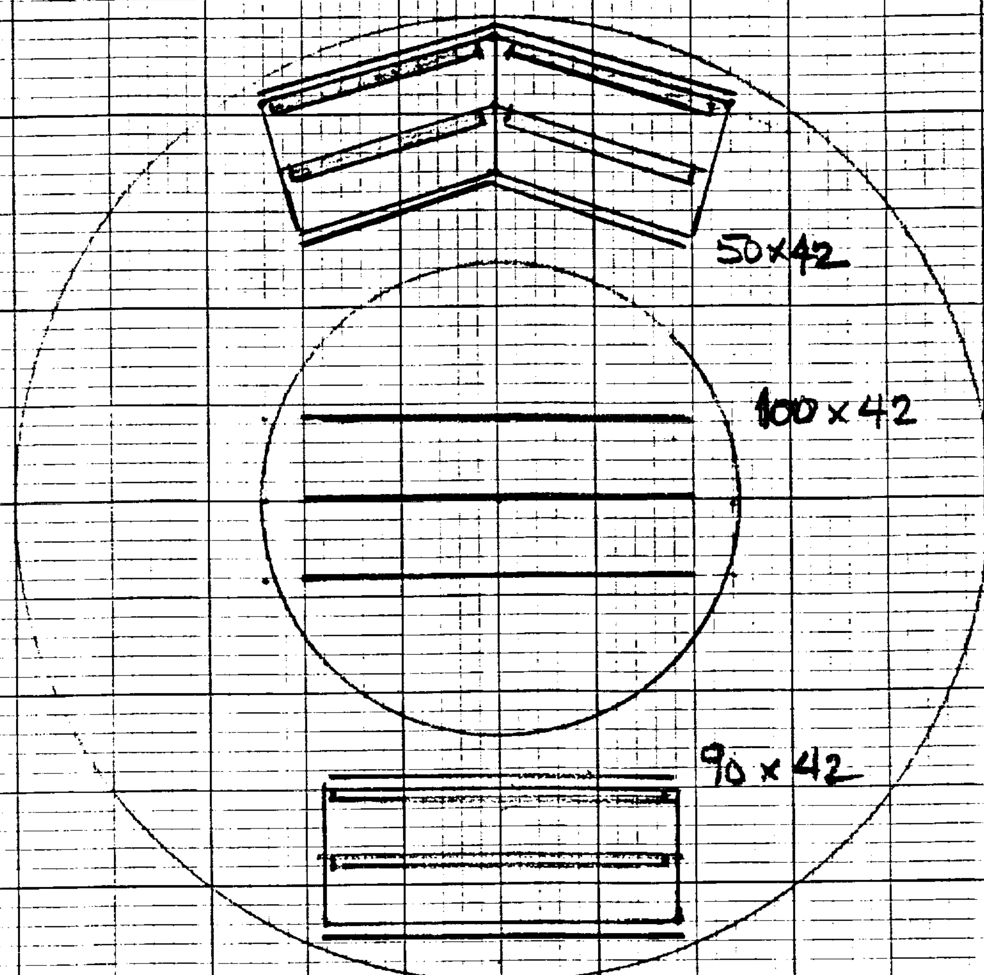

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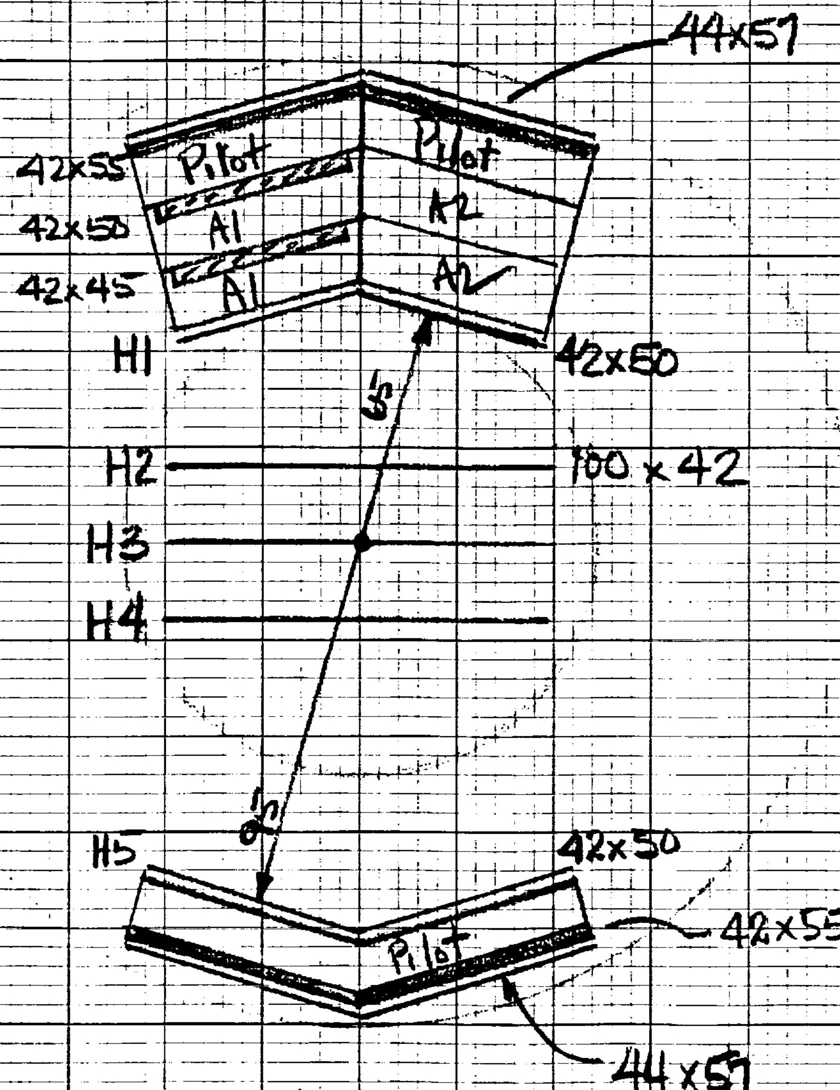
Fig. 4

Delta Version
#7



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